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DRY BEAN AGRONOMY: OPTIMIZING THE DRYLAND PRODUCTION SYSTEM

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Dry Bean Agronomy: Optimizing the Dryland Production System

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1 Abstract

The objective of this study was to refine the narrow-row agronomic production practice for the dry bean cultivar CDC Pintium and to evaluate the cultivar Envoy. Inoculation with Rhizobium had no effect on the yield of dry bean under dryland or irrigated production. The addition of nitrogen fertilizer increased yield in dry bean. Under irrigated production there was on average 2.5 kg ha-1 of dry beans produced for every kg ha-1 of nitrogen fertilizer that was added. Under irrigation the ratio was 6.3:1. Under dryland production producers should add 50 kg ha-1 when soil N levels are low. Levels will usually be economic under irrigation. Producers should avoid soaking dry bean seed whenever possible as this can reduce emergence. Producers should also use a seed fungicide that controls Fusarium. A no-till or spring tillage only, tillage system consistently provided the highest yields compared to fall and spring tillage and burning. CDC Pintium is adapted for production in Saskatchewan. Due to its longer growing season and reduced yield potential Envoy is not recommended as a bean variety in Saskatchewan.

2 Executive Summary

Please see the above abstract.

2.1 Background

The overall objective of this research is to refine the narrow row agronomic package for dry bean production in the thin black soil zone of Saskatchewan. The CDC has developed dry bean varieties adapted for dryland production. These adaptations include upright growth, short growing season and improved pod clearance. What is now needed is for the agronomic package to be refined to allow producers to profitably grow this crop.

2.2 Experiments Overview

The varieties used in each experiment were selected because of similar growing characteristics. CDC Pintium is a large seeded pinto type bean variety. It is early maturing and has a good pod clearance. Its average seed weight is 350 grams per 1000 seeds. Envoy is a small seeded navy type bean. It is a medium

maturing variety with good pod clearance. It has an average seed weight of 150 grams per 1000 seeds. CDC Expresso is a black bean with medium maturity and very good pod clearance. It has an average seed weight of 191 grams per 1000 seeds. Variety differences in maturity, seed weights and yield are seen in each of experiments 2, 3, and 4.

Even though CDC Pintium is well suited to Saskatchewan with very high yield potential, is has still been a very challenging crop to grow. Each year that the experiments were conducted presented it own set of challenges including drought, frost, and hail. 2001 through 2003 were three of the driest years in Saskatchewan history (Table 1). In some locations this resulted in very low yields and seed weights. In 2002, frost destroyed the experiments at Rosthern, Saskatoon, and Melfort sites on August 2nd and 4th, and significant frost damage occurred at Redvers. On July 6, 2003, a hailstorm destroyed the Rosthern site. Due to these climatic conditions, full data sets were not obtained from each site for all years. Nevertheless, because of the large number of locations that these trials were ran at, we were still able to collect enough data to make recommendations.

This project was not possible without two cooperators who grew some of the experiments at other locations. Agriculture and Agrifood Canada (AAFC) grew two of the experiments each year at Melfort. Terry Hogg of SIDC grew the Pintium treatments of two of the experiments for three years as well. This irrigated production was especially important to this study to give it some application beyond the dry environmental conditions that were encountered under dryland production.

Table 1. Average season monthly tempuratures (°C) and cumulitive precipitation (mm) for all locations from 2001 to 2003.

Year	Location	April	May	June	July	August	September
				Average Temperature (°C)			
2001	Saskatoon	4.2	11.8	15.1	19.4	19.8	13.5
	Rosthern	4.7	12.7	15.5	19.6	19.8	14.2
	Redvers	4.3	12.7	15.3	19.1	19.6	13.1
	Melfort	3.5	11.5	14.1	18.6	19	13.3
2002	Saskatoon	-1	8.4	17	20	16.2	10.8
	Rosthern	-0.2	8.7	17.3	20	16.7	11
	Redvers	1.6	8.3	16.8	19.8	16.7	12.5
	Melfort	-2.1	7.3	17.2	19.6	16.1	10.7
2003	Saskatoon	4.6	11.8	15.9	18.2	20.6	11.3
	Rosthern	5.1	12.4	16	18.9	21.1	11.4
	Redvers	5.3	11.8	16.2	19.6	21.2	12
	Melfort	3.7	12.2	15.7	18.1	19.8	10.4
				Precipitation (mm)			
2001	Saskatoon	5.8	26.4	35.6	53.6	11.4	11.2
	Rosthern	22.6	26.6	42.8	81.6	4.6	7.4
	Redvers	22.2	37.6	129.2	129.6	5	6
	Melfort	17.7	12	20.4	46.4	11.4	10.6
2002	Saskatoon	13.1	0.0T	73	71.6	85.7	59
	Rosthern	13.4	3.4	87.8	45	84.2	48
	Redvers	15.6	21.2	86.8	93.8	125	17.6
	Melfort	16.7	4.8	56.2	58	128.6	42.8
2003	Saskatoon	61.2	13.8	30.8	63.9	31.4	38.7
	Rosthern	59	18.8	34.2	73.8	47	50
	Redvers	38.4	39.8	38.8	30.6	21	14.7
	Melfort	26.2	49.6	52	35.8	24.4	23.2

3.1 Experiment 1 – The Effect of Nitrogen Fertilizer and Rhizobium on the Yield and Maturity of CDC Pintium

3.1.1 Objective:

The objective of this experiment is to determine the interaction between varying rates of nitrogen fertilizer and rhizobium on the dry bean variety Pintium.

3.1.2 Materials and Methods:

The experiment is a two factor, factorial randomized complete block design conducted at Saskatoon, Rosthern, Redvers, Melfort and Outlook. All sites were dryland except for Outlook which was irrigated. The variables include nitrogen rate (0, 25, 50, and 75 kg actual N ha^{-1}) and inoculation (with and without rhizobium inoculation). The beans were direct seeded into standing stubble in 20 cm rows at a target density of 45 plants m^{-2}. The beans were planted in 20.3 cm rows with a target density of 45 plants m^{-1} (exception: Melfort had 17.8 cm rows). A granular inoculant (Nodulator, by Becker Underwood) specific to dry bean, was added to the seed row of specified treatments at a rate of 5.65 kg ha^{-1}. Nitrogen fertilizer was side banded as 46-0-0 at seeding 2.5 cm below and 2.5 cm to the side of the seed. The rhizobium free treatments were seeded first to avoid contamination. CDC Pintium was treated with Vitaflo 280 and Apron FL at the label rate prior to seeding. Each site had a fall application of Edge or Pursuit (1/3 label rate), a pre-seed burn-off with glyphosate, and in-crop weed control with a group 1 herbicide (for grassy weed control) and Basagran (for broadleaf weed control). All herbicides were applied at recommended rates for the weed species that were present in a given year except where noted. Supplemental hand weeding was also done as required. Nodules were evaluated using a scoring system by Rice and Clayton (Agriculture and Agri-food Canada), 1996. Further experimental details are included in Table 2. The beans were straight harvested when mature and were dried to constant moisture content before weighing. Due to problems with drought, hail and frost only 12 of the 15 sites were taken to yield.

Data was analyzed using the Mixed procedure of SAS with site and year as random effects and irrigation as a fixed effect. Melfort 2002 was not included in the combined analysis due to extremely low yields (ca. 300 kg ha-1). Analysis was also performed on individual site-years.

Table 2. Seeding Date, average percent emergence, and harvest date for dry bean in 2001-2003

Year	Location	Planting Date	CDC Pintium average % emergence	Interrow Width (cm)	Harvest date	Soil climatic zone	Soil texture
2001	Saskatoon	May-23	68.6	20.3	DROUGHT	Dark brown	Clay loam
	Rosthern	May-25	80	20.3	Sep-20	Black	Clay loam
	Redvers	May-31	118	20.3	Sep-20	Black	Clay loam
	Melfort	Jun-01	70	17.8	Sep-07	Moist Black	Clay loam
2002	Saskatoon	May-31	59.8	20.3	FROST Aug 2	Dark brown	Clay loam
	Rosthern	Jun-03	52.4	20.3	FROST Aug 2	Black	Clay loam
	Redvers	Jun-05	37.6	20.3	Sep-26	Black	Clay loam
	Melfort	May-29	58.6	17.8	Oct-10	Moist Black	Clay loam
2003	Saskatoon	May-29	87.6	20.3	Sep-04	Dark brown	Clay loam
	Rosthern	May-28	96.9	20.3	HAIL Jul-06	Black	Clay loam
	Redvers	May-27	102	20.3	Sep-24	Black	Clay loam
	Melfort	May-27	44	17.8	Sep-26	Moist Black	Clay loam

Table 3. Soil Test Nutrient Levels (lbs/ac)

Year	Location	Depth (In)	NO_3-N	P	K	SO_4-S
2001	**Saskatoon**	**0-12**	20	22	893	38
	Rosthern	**0-12**	48	36	810	38
	Redvers					
	Melfort	**0-12**	36.8	35	415	52
2002	**Saskatoon**	**0-12**	103	40	>1080	>86
	Rosthern	**0-12**	32	29	896	43
	Redvers					
	Melfort	**0-6**	31	>54	>540	41
2003	**Saskatoon**	**0-12**	12	24	750	20
	Rosthern	**0-12**	>160	20	738	44
	Redvers	**0-12**	10	28	>1080	46
	Melfort	**0-6**	17	56	575	28

3.1.3 Results and Discussion:

Inoculating the beans with rhizobium had no overall effect on yield ($P = 0.606$) nor did it have a significant effect on yield at any of the site year combinations (Table 4 and 5). The only site that showed a biological response was Outlook in 2002 where the yield with inoculation was 250 kg/ha higher ($P = 0.126$) (Table 5). A contrast was used to compare the yield response of rhizobium inoculation at only the 0 N treatment. At Outlook in 2001 the yield of bean increased by 645 kg ha-1 when inoculated with rhizobium with no N added. This may indicate that when nitrogen fertilizer is not added and there is a high yield potential, the yield of bean may respond to inoculation with Rhizobium. However, no other site showed a positive response and in fact Melfort in 2001 showed a negative response ($P = 0.06$) to added rhizobium with no nitrogen added. We have no explanation for this result.

Table 4. Analysis of variance for the effect of nitrogen rate (RR), rhizobium inoculation (R) and irrigation (I) on the yield of CDC Pintium. Combined analysis for 11 sites.

Effect	Num. DF	Den. DF	F Value	Pr > F
Nitrogen Rate (NR)	3	7.64	11.22	0.0035
Rhizobium Inoculation (R)	1	2.02	0.37	0.6057
Irrigation (I)	1	6.82	140.23	<.0001
I * NR	3	7.64	2.31	0.1562
I * R	1	2.02	0.33	0.6230
NR * R	3	20.3	0.17	0.9133
I * NR * R	3	20.3	1.41	0.2678

In contrast to the lack of yield response to rhizobium inoculation is the response to nitrogen fertilizer (Table 4). Overall there was a positive response to N fertilizer. Both irrigated and non-irrigated beans responded to N fertilizer but the response was greater under irrigated production (Figure 1). There was a significant linear response to added nitrogen fertilizer at seven of the eleven sites (Table 5). There was always a significant response under irrigation, indicating the importance of adequate water for high yield potential.

Table 5. The effect of Rhizobium inoculation and nitrogen fertilizer rate on the yield of Pintium dry beans at individual sites. F- values and significance of the fixed effects were calculated using PROC MIXED of SAS®.

		Melfort 2001	Melfort 2002	Melfort 2003	Outlook 2001	Outlook 2002	Outlook 2003	Redvers 2001	Redvers 2002	Redvers 2003	Rosthern 2001	Saskatoon 2003
Rhizobium Inoculation (R)	0 kg ha^{-1}	980	306	1503	3097	2696	3366	1198	1234	1327	1136	1024
	5 kg ha^{-1}	894	264	1541	3347	2255	3350	1182	1257	1418	1168	911
	P>F	*0.332*	*0.3684*	*0.663*	*0.127*	*0.510*	*0.883*	*0.908*	*0.782*	*0.364*	*0.720*	*0.152*
Nitrogen Fertilizer Rate (NR) kg actual N ha^{-1}	0 kg N ha^{-1}	1039	241	1418	2802	2475	3200	1061	1098	1179	1090	794
	25 kg N ha^{-1}	1027	268	1549	3140	2895	3333	1200	1198	1359	1141	958
	50 kg N ha^{-1}	812	358	1573	3471	2856	3343	1222	1299	1324	1193	992
	75 kg N ha^{-1}	871	274	1548	3476	2934	3557	1277	1388	1629	1184	1124
	P>F	*0.195*	*0.307*	*0.532*	*0.018*	*0.073*	*0.177*	*0.725*	*0.103*	*0.026*	*0.845*	*0.042*
N vs. 0 N	**P>F**	*0.206*	*0.269*	*0.155*	*0.005*	*0.010*	*0.111*	*0.291*	*0.050*	*0.032*	*0.443*	*0.015*

NR Linear	**P>F**	*0.082*	*0.358*	*0.295*	*0.003*	*0.032*	*0.039*	*0.289*	*0.015*	*0.006*	*0.421*	*0.006*
NR Quad.	**P>F**	*0.687*	*0.230*	*0.362*	*0.306*	*0.205*	*0.720*	*0.763*	*0.948*	*0.527*	*0.749*	*0.841*
R at 0 N	**P>F**	*0.064*	*0.444*	*0.341*	*0.054*	*0.105*	*0.736*	*0.728*	*0.661*	*0.280*	*0.269*	*0.518*
C x SR	**P>F**	*0.3287*	*0.920*	*0.640*	*0.408*	*0.143*	*0.489*	*0.846*	*0.970*	*0.838*	*0.018*	*0.640*

[z] Least Significant Difference for the seeding rates is calculated for individual comparisons using PROC MIXED of SAS® and returns a range of LSDs for different comparisons. The highest of these values is presented here; the lowest was always within 60% of the highest.

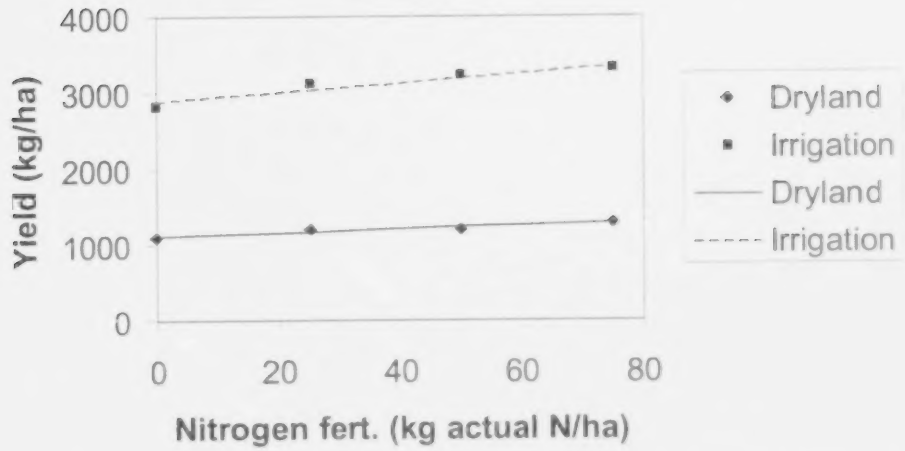


Figure 1. The effect of nitrogen fertilizer on the yield of irrigated (3 site-years) and dryland (8 site-years) bean yield. Lines show fitted linear regressions.

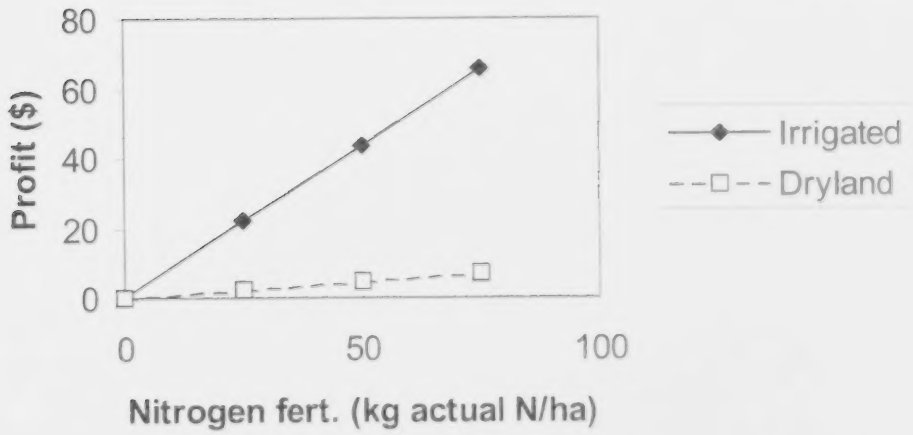


Figure 2. Average profit (3 sites-years for irrigation and 8 site-years for dryland) from adding nitrogen fertilizer to CDC Pintium dry bean assuming that the price of the beans is $.25 kg-1 and the actual nitrogen in the fertilizer is $0.40 kg-1.

Assuming a price for nitrogen fertilizer ($0.40/lb actual N) and dry beans ($0.25/lb) it would pay to add nitrogen fertilizer to CDC Pintium (Figure 3). However the returns under dryland production are much lower than they are under irrigated production. Under dryland production the break-even ratio for the price of actual N fertilizer compared to the price of beans is 2.5:1. This means that whenever the price of N is less than 2.5 times the price of beans it will be economical to fertilize on average. Under irrigation the return from fertilizing appreciates more and as long as the price of fertilizer is less that 6.3 times the price of beans it will be economic the fertilize.

This study was conducted during a period characterized by drought at many of the locations we were encouraged that overall there was an economic response to nitrogen fertilizer under dryland conditions (Table 1). In addition the soil N level was high at many of the dryland sites (Table 3). Given these conditions we were surprised that there was on average a positive economic return from fertilizing with nitrogen. We would have expected a much greater return if the soil N levels had been lower and there was more plant available moisture. Thus we will recommend the addition of nitrogen fertilizer when growing Pintium bean.

As previously discussed, the addition of rhizobium inoculant did not have an overall effect on bean yield at any of the sites-years (Table 5). This is not due to the rhizobium inoculant being ineffective. There was a significantly higher amount of nodules observed on plants treated with rhizobium in 2001 and 2002 (Figure 3) at Rosthern and Redvers. This indicates that the rhizobium had infected the roots of the bean plant but resulted in no benefit to the plant. In 2001 at Saskatoon and Redvers, and 2003 at Saskatoon, there was no significant increase in the number of nodules. This may be due to poor root infection because of the extremely dry conditions in the spring.

The addition of nitrogen or inoculation had no overall effect on CDC Pintium individual seed weight (Table 6). Two of the site years had a slight increase in seed weight with increased nitrogen but the differences were small (data not shown). Overall this effect is of no agronomic concern.

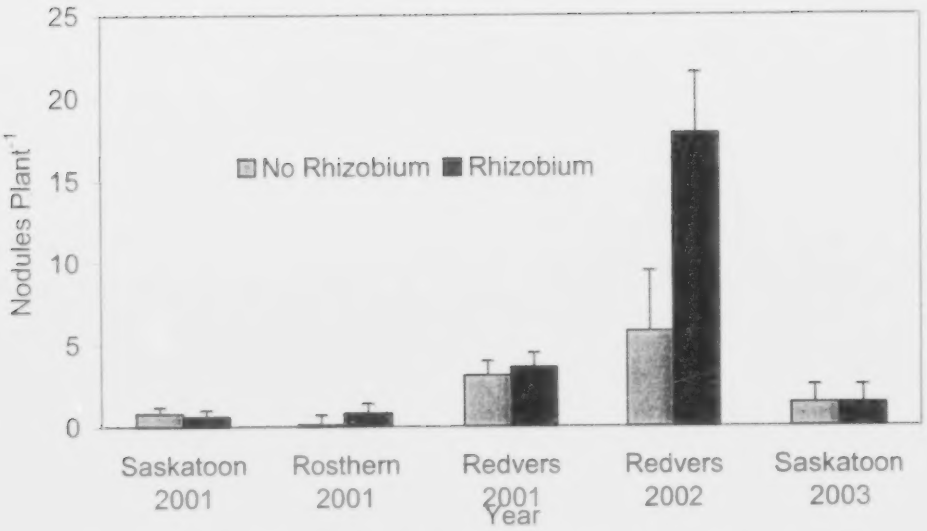


Figure 3. The effect of rhizobium inoculation on nodulation of CDC Pintium.

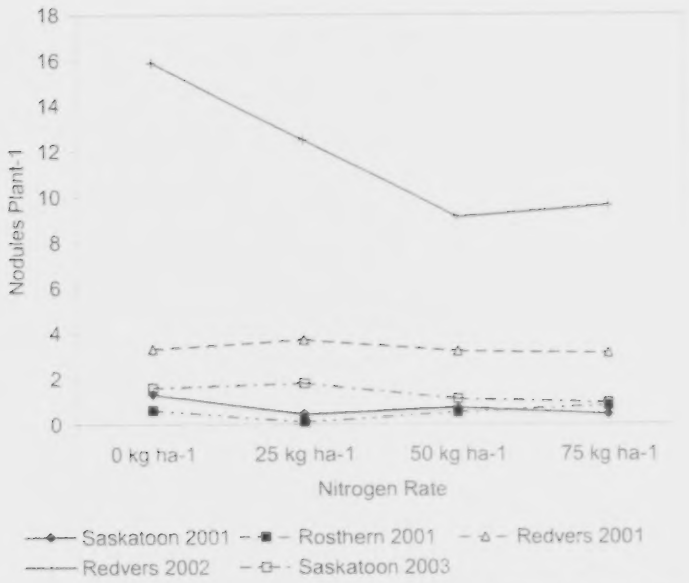


Figure 4. The effect of nitrogen fertilizer rate on the nodulation of dry bean at individual sites.

Table 6. Analysis of variance for the effect of nitrogen rate (NR), rhizobium inoculation (R) and irrigation (I) on the individual seed weight of CDC Pintium. Combined analysis for 11 sites.

Effect	Num DF	Den DF	F Value	Pr > F
Nitrogen Rate (NR)	3	5.95	0.18	0.9087
Rhizobium Inoculation (R)	1	1	0.67	0.5635
Irrigation (I)	1	2.04	3.91	0.1840
I * NR	3	39.7	0.21	0.8903
I * R	1	1.39	0.12	0.7743
NR * R	3	38.8	1.74	0.1746
I * NR * R	3	38.8	0.26	0.8553

The addition of nitrogen decreased nodulation at Saskatoon 2001 and Redvers 2002 for dry bean (Fig. 2). Other sites showed little effect of fertilizer nitrogen on nodulation. Perhaps this is due to the relatively high soil N levels and dry environments experienced at some locations (Tables 2 and 3).

There was no significant treatment effects from the addition of nitrogen or Rhizobium on days to flowering or maturity from 2001 to 2003. CDC Pintium had an average maturity of 91 days. However one of the four sites that experienced an early frost (Rosthern 2001) that caused seed damage had higher levels of frost damage with increased nitrogen.

3.2 Experiment 2 –The Interaction of Seeding Rate and Nitrogen Fertilizer on Dry Bean Yield and Maturity

3.2.1 Objective:

The objective of this experiment is to determine the effects of seeding rate and nitrogen fertilizer rate on dry bean yield and maturity. We hypothesized that adding nitrogen fertilizer will cause greater growth in individual dry bean plants which could result in a lower seeding rate recommendation when dry bean are fertilized with nitrogen.

3.2.2 Materials and Methods:

The experiment is a 3 factor, factorial randomized complete block design conducted at Saskatoon, Rosthern, Redvers, Melfort and Outlook. The Outlook site was irrigated, all other sites were not. The variables include seeding rate, nitrogen rate and variety. CDC Pintium (type 1 - pinto), and Envoy (type 1 - navy), was seeded at 20, 40, 60, and 80 plants m^{-2}. At Outlook only CDC Pintium was grown. The beans were seeded in 20.3 cm rows with the exception of Melfort which had 17.8 cm rows. Nitrogen fertilizer was banded 2.5 cm to the side and 2.5 cm deeper than the seed, at rates of 0, 50, and 100 kg ha^{-1}. Other experimental details are given in table 7. All treatments were inoculated with granular rhizobium within the seed row. The seed was also treated with Vitaflo 280 and Apron FL at the recommended rates. The experiment was seeded into standing stubble at all locations with the exception of Outlook. Weeds were controlled as previously described.

The experiment was analyzed using the Mixed procedure of SAS. Irrigation, seeding rate, variety and nitrogen rate were considered fixed effects. Site and year were considered random effects. Because of drought at several locations and problems with the data at one location (Redvers 2001) only Melfort 2001, Melfort 2003, Saskatoon 2003, Redvers 2002, Redvers 2003, Outlook 2001, Outlook 2002 and Outlook 2003 were combined for the economic analysis. Data from Rosthern 2001 and Melfort 2002 was analyzed but not in the combined model as these sites had reduced yields at higher seeding rates due to drought conditions. As Envoy was not grown at Outlook it could not be analyzed in this model. A separate combined model for dryland sites was used to analyze the yield of Pintium and Envoy. Other parameters were analyzed within individual sites.

Table 7. Seeding Date, average percent emergence, and harvest date for dry bean in 2001-2003

Year	Location	Planting Date	CDC Pintium average % emergence	Envoy average % emergence	Interrow Width (cm)	Harvest date	Soil climatic zone	Soil texture
2001	Saskatoon	May-23	73	71.2	20.3	DROUGHT	Dark brown	Clay loam
	Rosthern	May-25	86.4	88.6	20.3	Sep-24	Black	Clay loam
	Redvers	May-31	66.4	68.4	20.3	Sep-26	Black	Clay loam
	Melfort	Jun-01	83.4	74.8	17.8	Sep-07	Moist Black	Clay loam
2002	Saskatoon	May-31	70.8	78.8	20.3	FROST Aug 2	Dark brown	Clay loam
	Rosthern	Jun-03	65.6	73.6	20.3	FROST Aug 2	Black	Clay loam
	Redvers	Jun-05	68.9	62	20.3	Oct-10	Black	Clay loam
	Melfort	Jun-01	76.4	84.3	17.8	Oct-10	Moist Black	Clay loam
2003	Saskatoon	May-29	84.2	67	20.3	Sep-16	Dark brown	Clay loam
	Rosthern	May-28	88.4	68	20.3	HAIL Jul-06	Black	Clay loam
	Redvers	May-27	76.4	65.3	20.3	Sep-24	Black	Clay loam
	Melfort	May-27	104.7	84.4	17.8	Sep-26	Moist Black	Clay loam

3.2.3 Results and Discussion:

3.3.3.1 Irrigation and Dryland Production of Pintium

Increasing seeding rate increased yield in Pintium at most locations (Table 8, Figure 6). In general increasing seeding rate from 20 seeds m^{-2} to 40 seeds m^{-2} resulted in large yield gains.

The average yield increase in response to seeding rate under irrigation was greater than under dryland production (Figure 7). To determine the optimum economic seeding rate an economic analysis was conducted. Two scenarios were considered: 1) High seed costs where the cost of seed per unit is 2.4 times that of the harvested seed and the seed weight was 400mg and 2) Low seed costs, where the cost of seed was 1.5 times that of the harvested seed and the seed weight was 340 mg. Under dryland conditions returns were maximized at a seeding rate of approximately 40 seeds m^{-2} (Figure 8). Under irrigated conditions a seeding rate of approximately 60 seeds m^{-2} maximized returns.

These results suggest that farmers growing Pintium beans should have a seeding rate of approximately 40 seeds m^{-2} under dryland conditions 60 seeds m^{-2} under irrigated conditions. Closer inspection of the results from individual locations (Figure 6) reveals that under dryland production increasing the seeding rate from 20 to 40 seed m^{-2} usually results in a large yield increase. Even in the two situations where yield did not increase with increase seeding rate, the yield at 40 seeds m^{-2} was very close to being the highest yield. Whether an increase to 60 seeds m^{-2} under irrigation is warranted is not as clear. Only at Outlook in 2001 was there a large increase in yield from 40 to 60 seed m^{-2}. Because of this inconsistency producers should probably seed 40 viable bean seeds m^{-2} under both dryland and irrigated conditions. This seeding rate recommendation is probably higher than many producers are currently using. A common seeding rate is 120 lbs per ac (105 kg ha^{-1}). At a seed weight of 350mg per seed, this equates to a seed density of 25 seeds m^{-2}. By changing to a seeding rate of 30 seeds m^{-2} producers could increase their bean yield by approximately 100 kg ha^{-1} under dryland production and 200 kg ha^{-1} under irrigation.

Contrary to our hypothesis, seeding rate and nitrogen rate did not have an interaction (Table 8). This indicates that these variables respond in an additive fashion and not a multiplicative and can be considered separately. Thus we will consider the seeding rate and nitrogen separately.

Table 8. Combined analysis of variance for the yield of Pintium as effected by seeding rate (SR), nitrogen fertilizer (NR) and irrigation (I) at eight site-years.

Effect	Num DF	Den DF	F Value	Pr > F
Seeding Rate (SR)	3	3.69	20.02	0.0093
Nitrogen Rate (NR)	2	11.8	11.71	0.0016
Irrigation (I)	1	6.81	115.23	<.0001
I * SR	3	3.69	1.14	0.4413
I * NR	2	11.8	3.24	0.0757
SR * NR	6	36.6	0.46	0.8352
I * SR * NR	6	36.6	0.56	0.7580

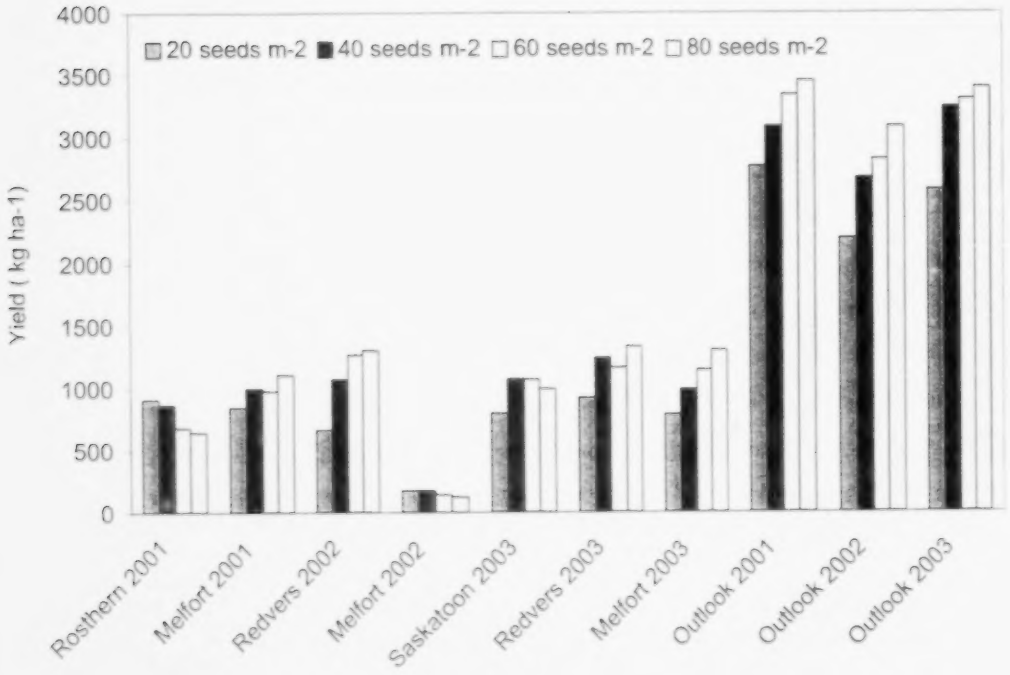


Figure 6. The effect of seeding rate on Pintium dry bean yield at individual locations.

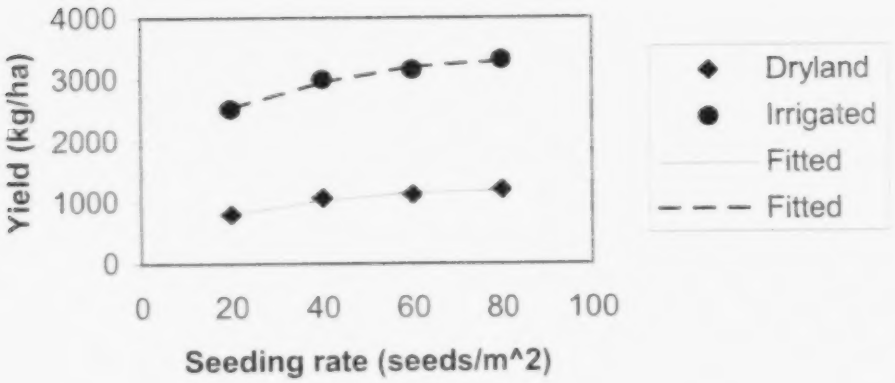


Figure 7. The effect of seeding rate on yield of irrigated and dryland Pintium dry bean. Fitted lines are quadratic regressions.

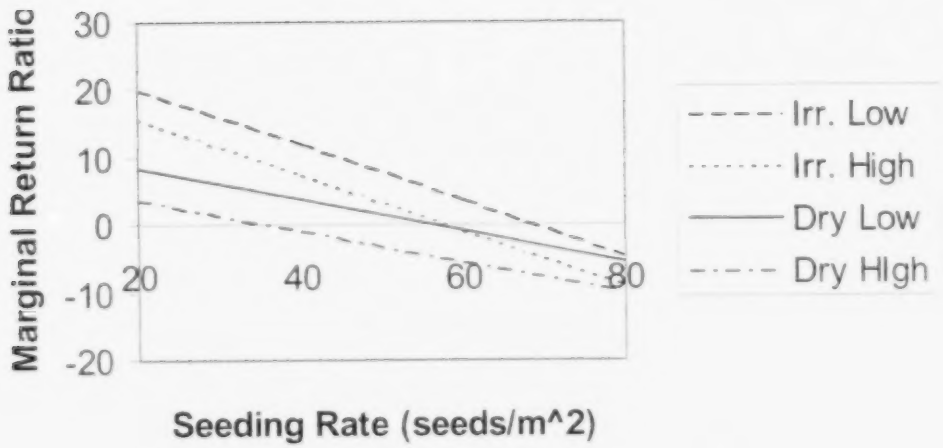


Figure 8. The effect of seeding rate in Pintium dry bean on the marginal return ratio with high and low seed costs under irrigated (Irr.) and dryland (Dry) production. A positive ratio indicates that each addition increase in seeding rate is increasing the net return.

Increasing nitrogen fertilizer increased yield of Pintium under both dryland and irrigated conditions (Table 8, Figure 9). Each additional kg of N increased the bean 1.7 kg ha^{-1} under dryland conditions and 5.5 kg ha^{-1} under irrigated conditions (data not shown). These ratios are similar to those reported in experiment 1 of this report. Given this, if the price of beans to be sold is greater than 1.7 times the price of the actual nitrogen in the nitrogen fertilizer, it will pay to fertilize under dryland conditions. Under irrigated conditions return from N fertlizer is much greater. It should be noted that the soil nitrogen levels were not very low in this trial (Table 3). Given that there was still an N response under these conditions demonstrates the utility of nitrogen fertlizer in dry bean productions. This effect was explored in much more detail in experiment 1.

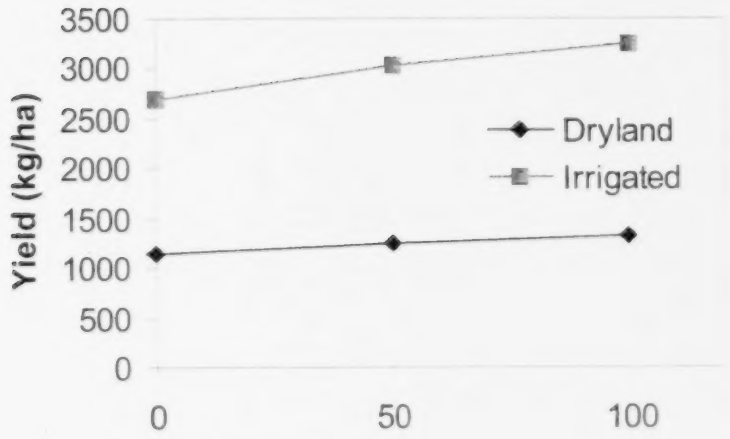


Figure 9. The effect of nitrogen fertilizer on the yield of Pintium dry bean under dryland and irrigated conditions.

Increasing seeding rate does significantly lower individual seed weight in Pintium (Table 9, Figure 10). Nonetheless the reduction is small and reduced the average seed weight from 365 mg to 344 mg. Conversely increasing nitrogen fertilizer results in a small gain in seed weight

(Table 9, Figure 11). Adding 100 kg ha^{-1} of actual nitrogen fertilizer increase the seed weight from 250 mg to 356 mg. Given there are not usually discounts for small reductions in seed size this effect is of little significance to dry bean growers.

Table 9. Combined analysis of variance for the seed weight of Pintium as effected by seeding rate (SR), nitrogen fertilizer (NR) and irrigation (I) at eight site-years.

Effect	Num DF	Den DF	F Value	Pr > F
Seeding Rate (SR)	3	2.02	23.19	0.0408
Nitrogen Rate (NR)	2	321	4.01	0.0190
Irrigation (I)	1	3.96	3.45	0.1375
I * SR	3	2.02	0.70	0.6311
I * NR	2	321	1.00	0.3700
SR * NR	6	319	1.61	0.1448
I * SR * NR	6	319	0.86	0.5234

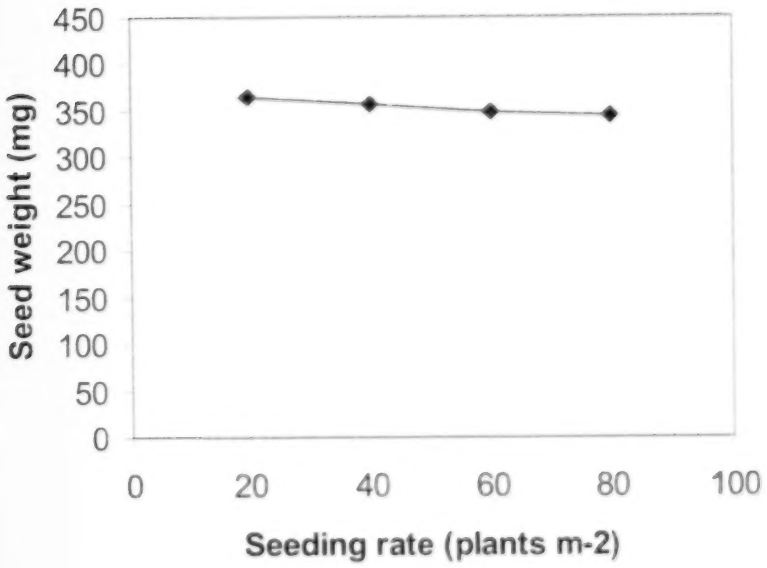


Figure 10. The effect of seeding rate on the seed weight of Pintium dry bean.

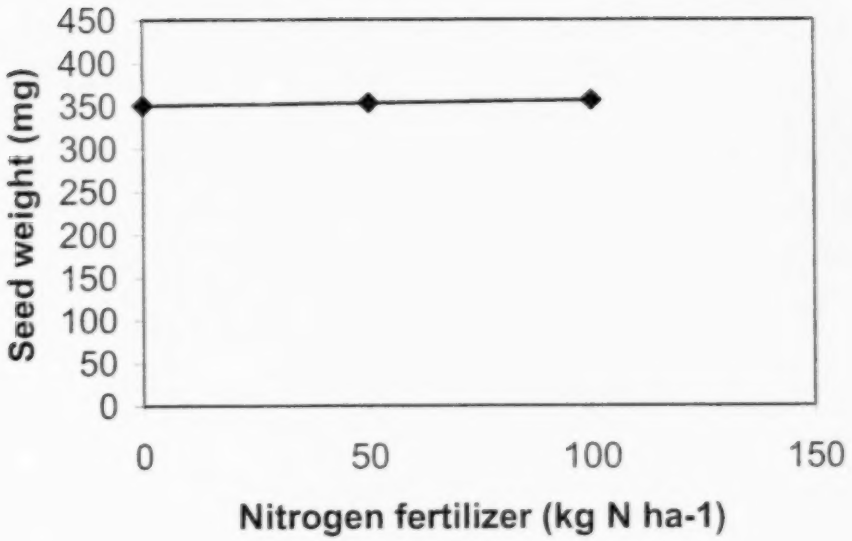


Figure 11. The effect of nitrogen fertilizer on the seed weight of Pintium dry bean averaged over all locations.

3.3.3.1 Pintium and Envoy Dryland Production

Under dryland conditions Pintum had a higher yield than Envoy (Table 10 and Figure 12 and 13). The variety by nitrogen interaction and the variety by seeding rate interactions were weak but they serve to illustrate the difference in yield potential between these two varieties. Pintium had a greater response to both increased seeding rate (Figure 12) and increased N fertilizer (Figure 13). We believe that this occurred because Pintium is more adapted to the short dry seasons encountered under dryland production in Saskatchewan.

As expected the seed weight of Pintium was much higher than Envoy. The effect of seeding rate and nitrogen fertilizer on seed weight in Pintium and Envoy grown under dryland conditions were similar to those previously observed in Pintium. Seeding rate and nitrogen fertilizer affected the seed weight (Table 11) but the effects were small (data not shown). Interestingly, Pintium had a larger reduction in seed weight compared to Envoy as seeding rate increased. The reasons for this interaction are not known.

Days to flower was relatively unaffected by seeding rate and nitrogen fertilizer (Table 12). Increasing seeding rate from 20 to 80 seeds m^{-2} reduced days to first flower by 0.5 day. Only Redvers 2002 experienced a frost. Frost damage was much higher in the later maturing Envoy. Nitrogen fertilizer increased frost damage by 1.8% of the total beans whereas increasing seeding rate reduced frost damage slightly (Table 12). The increase in frost damage with nitrogen fertilizer is probably due to a delay in maturity.

The addition of nitrogen did not affect the maturity of dry bean in 2001-2003 at any locations with the exception of Saskatoon in 2003. Here, the days to maturity of the 50 and 100 kg ha^{-1} nitrogen rates was significantly higher than the 0 kg ha^{-1} rate. The average days to maturity of CDC Pintium were 94.6 days and 102.9 days for Envoy.

Nitrogen fertilizer also increased the plant height at some locations including Redvers in 2003 (Figure 15). Where measured, nitrogen also slightly increased pod clearance. (Fig. 16). Given this one would expect fertlizer nitrogen to aid in the harvestability of dry beans.

Table 10. Combined analysis of variance for the yield dry bean as effected by seeding rate (SR), nitrogen fertilizer (NR) and variety (V) under dryland production for five site-years of production.

Effect	Num DF	Den DF	F Value	Pr > F
Seeding Rate(SR)	3	8.91	12.95	0.0013
Nitrogen Rate (NR)	2	7.1	1.74	0.2420
Variety (V)	1	1.6	10.02	0.1148
SR * NR	6	4.57	0.14	0.9830
NR * V	2	381	2.34	0.0981
SR * V	3	5.63	3.02	0.1215
SR * NR * V	6	381	1.11	0.3546

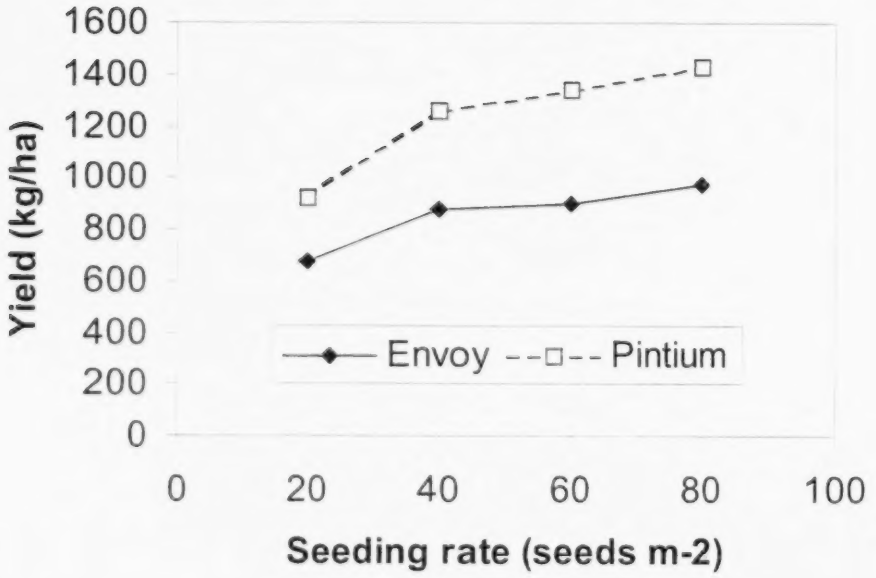


Figure 12. The effect of dry bean seeding rate on the yield of Envoy and Pintium beans at five locations under dryland production.

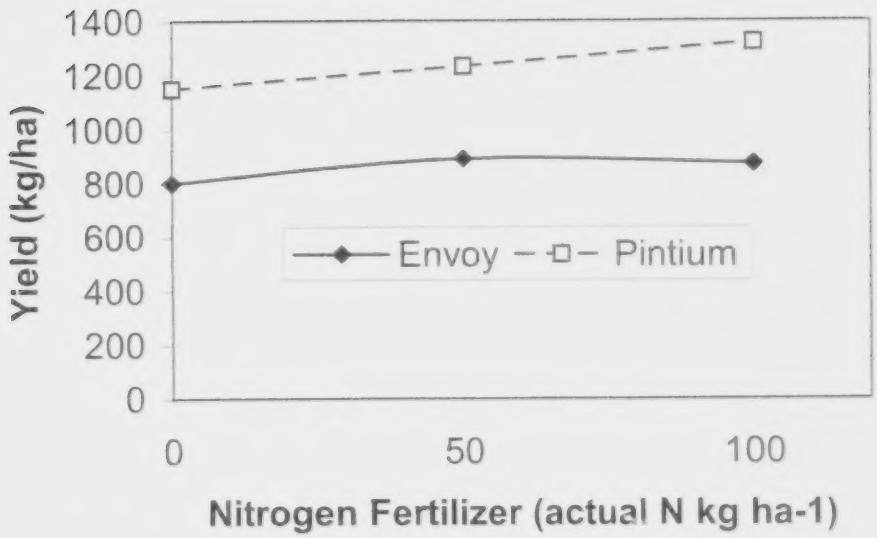


Figure 13. The effect of fertilizer on the yield of Envoy and Pintium beans at five locations under dryland production.

Table 11. Combined analysis of variance for the seed weight as effected by seeding rate (SR), nitrogen fertilizer (NR) and variety (V) under dryland production for five site-years of production.

Effect	Num DF	Den DF	F Value	Pr > F
Seeding rate (SR)	3	6.88	15.10	0.0021
Nitrogen rate (NR)	2	3.28	3.49	0.1542
Variety (V)	1	2.09	189.87	0.0043
SR * NR	6	404	1.75	0.1078
NR * V	2	404	1.53	0.2181
SR * V	3	6.88	6.96	0.0171
SR * NR * V	6	404	1.40	0.2119

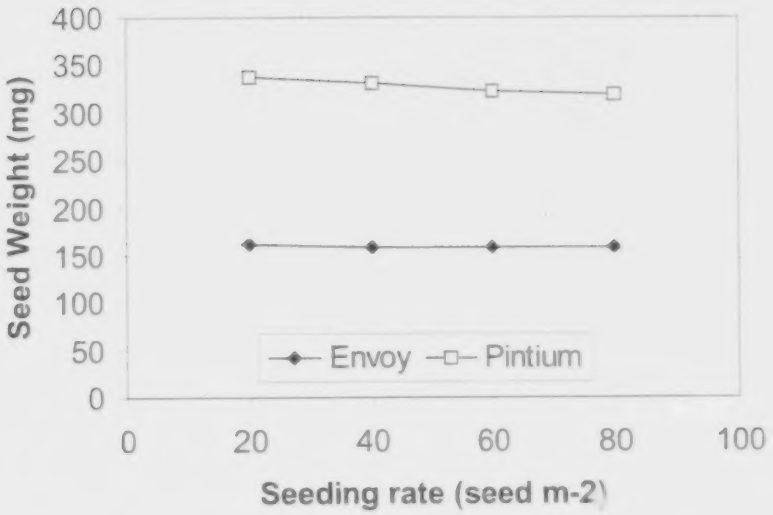


Figure 14. The effect of dry bean seeding rate on the yield of Envoy and Pintium beans at five locations under dryland production.

Table 12. Effect of Seeding Rate and nitrogen fertilizer on frost damaged beans at Redvers in 2002.

Seeding Rate (Seeds m^{-2})	Frost Damage (%)
20	5.67
40	4.75
60	4.13
80	3.87

Nitrogen Rate (kg ha^{-1})	Frost Damage (%)
0	3.69
50	4.81
100	5.31

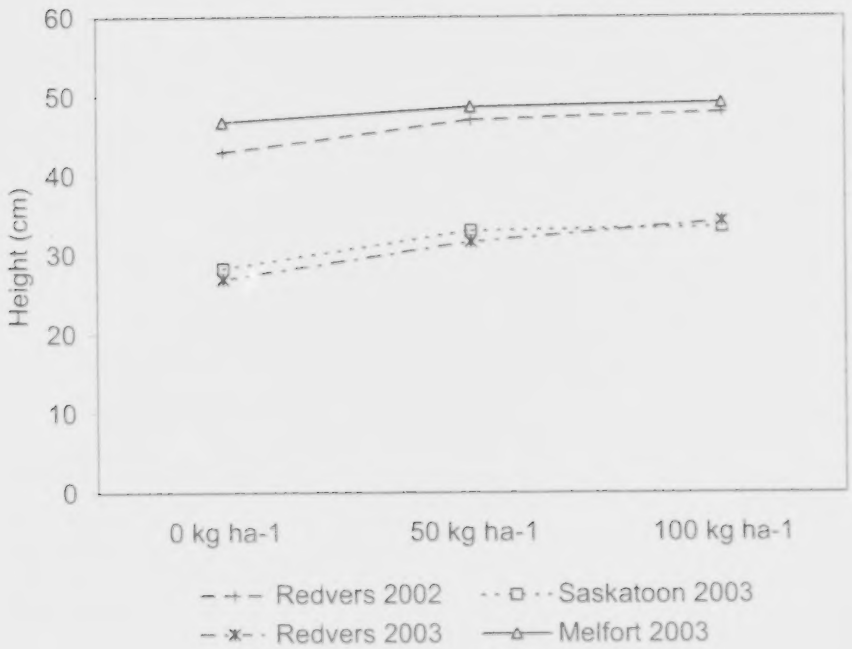


Figure 15. The effect of nitrogen rate on plant height at four locations.

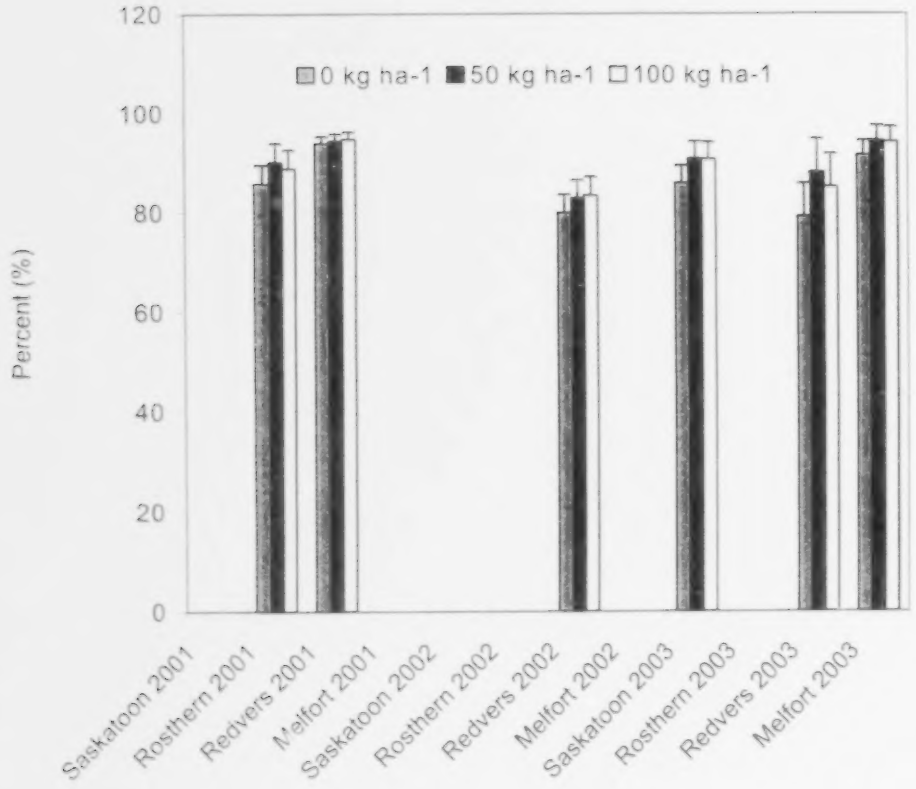


Figure 16. The effect of nitrogen fertilizer on pod clearance of dry bean grown under dryland conditions.

3.3 Experiment 3 – The Effect of Seed Fungicide on Emergence and Yield in Dry Bean

3.3.1 Objective:

The objective of this study is to the effect of seed treatment on emergence and yield in three market classes of dry bean. Root rot pathogens were not introduced in this experiment as the objective was not to determine the effect seed treatments on the pathology of root rot disease. Furthermore studies which inoculate the soil with pathogens greatly bias the experiment to have an emergence and yield response from seed treatments. Instead this experiment wished to determine the effect of seed treatments on the emergence and yield of dry beans under field conditions with indigenous plant pathogen populations in Saskatchewan.

3.3.2 Materials and Methods:

The experiment is a 2 Factor factorial RCBD conducted in Saskatoon, Rosthern, and Redvers. The variables include seed treatment and variety. CDC Pintium (type 1 pinto), CDC Expresso (type 1 black), and Envoy (type 1 navy) were seeded in 8 inch rows at a rate of 45 plants m^{-2}. Each variety was treated with label rates of DCT, Thiram, Apron FL, Vitaflo 280, Apron FL + Vitaflo 280, soaked, and untreated. All treatments had granular inoculum within the seed row. This experiment was seeded into standing stubble at Rosthern and tilled stubble at Redvers and Saskatoon in 2001, and standing stubble in 2002 and 2003.

Following seeding, emergence was recorded for all plants. At some of the sites, in the vegetative stage five plants per plot were exhumed and lesions on the roots were counted. Samples of the roots were plated out for the Saskatoon site in 2001 and 2003. Plots were harvested with a small plot combine when mature. Due to problems with drought, frost and hail damage yield data was available only for five of the nine site years. Experimental management details are given in Table 13.

The data were analyzed using the MIXED procedure of SAS. *A priori* contrasts were used to determine differences between specific treatments. Locations and years were considered random effects. The site years were also analyzed separately.

Identification of root rot pathogens

Non-germinated seeds or infected seedling were surface sterilized in 10% bleach solution for 5 min and plated onto tap water agar in Petri dishes. Petri dishes were evaluated 3 and 7 days after plating and evaluated for infection. Fungal colonies developing from infected seed or seedlings were transferred onto potato dextrose agar and incubated until sporulation. Mycelium and spores were used to identify the genus of the pathogen using a compound microscope (x 10 to x 80 magnification).

Table 13. Seeding Date, average percent emergence, and harvest date for dry bean in 2001-2003

Year	Location	Planting Date	CDC Pintium average % emergence	Envoy average % emergence	CDC Expresso average % emergence	Interrow Width (cm)	Harvest date	Soil climatic zone	Soil texture
2001	Saskatoon	May-23	74.9	74.7	58.7	20.3	DROUGHT	Dark browr	Clay loam
	Rosthern	May-25	81.5	86.2	71.1	20.3	Sep-24	Black	Clay loam
	Redvers	May-31	82.3	72.7	63.4	20.3	Sep-26	Black	Clay loam
2002	Saskatoon	May-31	70.2	78.2	75.6	20.3	FROST Aug 2	Dark browr	Clay loam
	Rosthern	Jun-03	66.2	66.6	50.2	20.3	FROST Aug 2	Black	Clay loam
	Redvers	Jun-05	63.5	65.3	50.2	20.3	Oct-10	Black	Clay loam
2003	Saskatoon	May-29	98.2	95.1	80	20.3	Sep-16	Dark browr	Clay loam
	Rosthern	May-28	96.9	78.7	87.1	20.3	HAIL Jul-06	Black	Clay loam
	Redvers	May-27	91.4	79.7	87.5	20.3	Sep-26	Black	Clay loam

3.3.3 Results and Discussion:

Overall seed fungicide treatment had little effect of dry bean emergence with no differences among seed treatments (Table 14 and Figure 17). However soaking untreated bean seeds before seeding

reduced emergence by 3.6% compared to the seed treatments (contrast $P = 0.0054$). This effect occurred at four of the nine sites and suggests that producers should avoid soaking dry beans prior to planting if possible. Nevertheless, we did not include a soaked treatment that had fungicide applied before or after soaking so we cannot comment on the interaction of soaking beans with fungicide application. We did not include soaking with fungicides treatments as this treatment was included as a separate check and we did not expect to see a difference between it and the un-soaked seed. We did not anticipate that soaking would have as profound an effect as was observed. To soak the beans we simply submerged the small quantity of beans we were to seed in water for a short time and allowed them to air dry. Compared with commercial methods of soaking seed in a mini-bulk bag, our seed would have probably remained wet for a shorter

time. Producers soak bean seed to increase the moisture content making them less susceptible to mechanical damage. However, if the beans are wet for to long the beans can swell causing the seed coat to become dislodged and the seed to split. Clearly this practice is risky and should be avoided when possible.

Table 14. The effect of seed treatment (seedtrt) on emergence in three varieties of dry bean (var). Analysis combined for nine dryland site-years.

Effect	Num DF	Den DF	F Value	Pr > F
seedtrt	6	12	3.11	0.0447
var	2	4	4.33	0.0999
seedtrt*var	12	672	0.98	0.4693

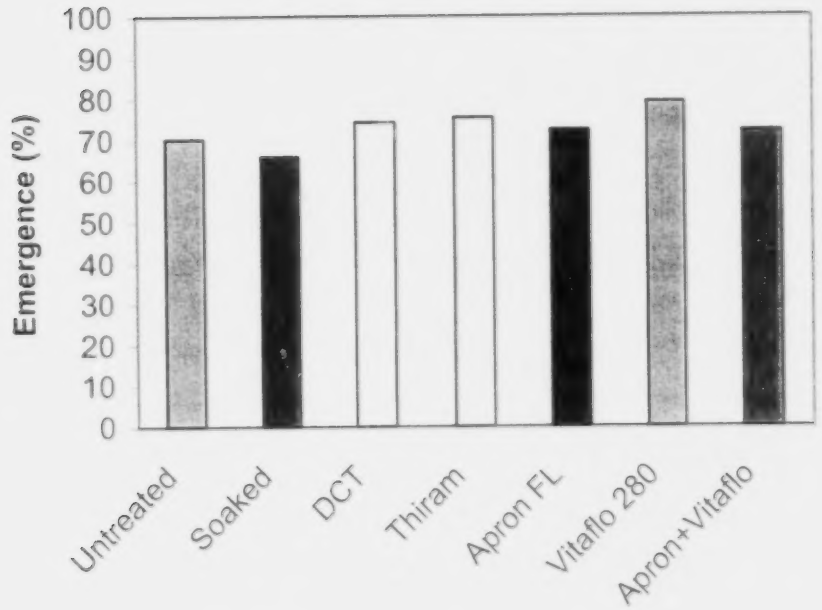


Figure 17. Field emergence of dry beans as affected by seed treatment averaged of nine site years. Soaked is lower than others (P = 0.0054).

The average emergence for all treatments was 73%. Overall there was no difference in emergence between the untreated control and the fungicide treated beans ($P = 0.117$). However at Redvers in 2003 seed treatment did increase seedling emergence from 78.9% to an average of 90% in the fungicide treated treatments ($P = 0.0063$). The lack of an overall difference between the seed fungicides and the control may be partially due to the experimental conditions. All three years in which this experiment was run had warm dry springs that are typically not conducive to seedling rot and root pathogen problems. In addition we did not supplement the soil with root rot pathogens as is often done in similar studies in order not to bias the results of the experiments in favor of seed treatment.

CDC Expresso had the lowest emergence at 66.8% followed by Envoy at 74% and CDC Pintium at 77%. The lower emergence of Expresso may be a result of the susceptibility of this variety to seed damage during harvest. We did not observe an overall interaction between bean variety and fungicide treatment (Table 14). We had expected that the black bean variety, CDC Expresso would have similar emergence in all treatments whereas the white coated variety Envoy would have poor emergence without seed fungicide treatments. We found no evidence for this in the overall analysis and little evidence for this in the analysis of individual sites. At Rosthern in 2002 the untreated controls in Envoy had lower emergence compared to the fungicide seed treatments whereas in the other varieties this did not occur ($P = 0.074$) (Figure 18).

Overall yield was unaffected by variety or seed fungicide treatment (Table 15). At individual sites there were few seed fungicide yield effects. At Redvers in 2002 soaking the beans resulted in lower yields and at Rosthern in 2001 beans grown from DCT treated seed had the higher yields than the other seed treatments. The lack of a seed treatment effect is not surprising as there was little difference in emergence between treatments that would have affected yield.

The number of root lesions were counted at Redvers, 2002, Redvers 2003, Rosthern 2001, Rosthern 2002, Saskatoon 2002 and Saskatoon 2003. The incidence of disease from these samples was very low. Only 7.8 % of the plants sampled had one or more lesions on the root system. Fungicide seed treatments did not reduce the number of root lesions compared to the control ($P = 0.86$). However, untreated seeds that were soaked had more root lesions than the fungicide treated seeds ($P = 0.093$). DCT had less root lesions than the other seed fungicide

treatments ($P = 0.054$). At Saskatoon in 2001 and 2003, plants with lesions were cultured in order to determine the pathogens present and only Fusarium spp. were found.

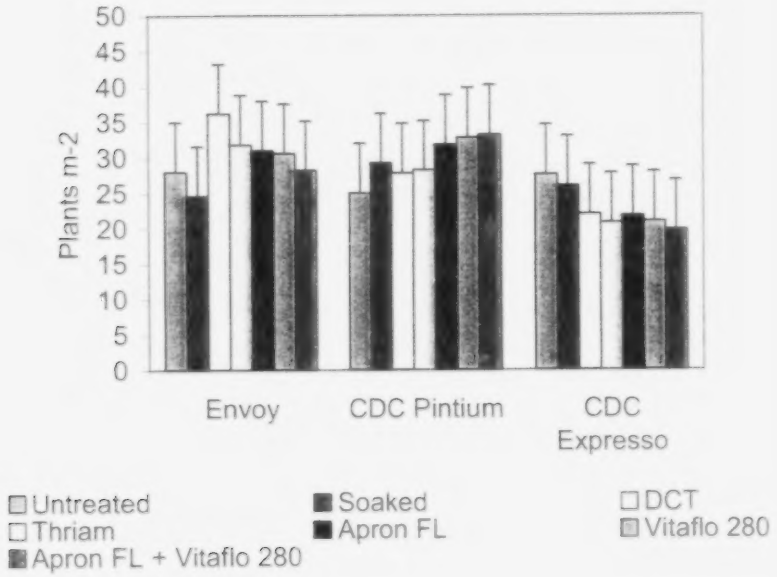


Figure 18. Field emergence of three dry bean varieties at Rosthern in 2002 as affected by seed treatment.

Table 15. The effect of seed treatment on crop yield in three varieties of dry bean. Analysis combined for nine dryland site-years.

Effect	Num DF	Den DF	F Value	Pr > F
seedtrt	6	18.5	0.72	0.6398
var	2	5.53	1.11	0.3945
seedtrt*var	12	24.4	0.52	0.8798

Seed weight, plant height, pod clearance, frost damage and plant maturity were not affected by seed treatments (data not shown).

In conclusion we have found that in the three years of this study seed treatment had little effect on seedling emergence and no effect on yield. We do wish to caution producers that this study was conducted in years when germination and emergence conditions were ideal. Had it been conducted in colder, wetter years we would have anticipated more profound differences. Nevertheless we can still draw some conclusions. As there was rarely a seed treatment by variety interaction we would recommend that all bean varieties (seed coat types) are treated with a seed treatment. As Fusarium was the only pathogen found on the beans a seed treatment that controls this species should be used. Furthermore producers should avoid soaking untreated seed prior to seeding. We saw emergence reductions in several locations from soaking seed. However, further research must be conducted to determine the effect of soaking seed in combination with seed treatments. Furthermore, seedling disease pressure may differ from what was observed in these experiments. In previous yield experiments, we have observed emergence as low as 30% in experiments and field trials. Given this, producers should continue to be cautious and use seed treatments to protect against root rot diseases in dry bean.

3.4 Experiment 4 – The Effect of Tillage System on Dry Bean Yield and Maturity

3.4.1 Objective:

The objective of this study is to determine the type of tillage system best suited to dry bean production.

3.4.2 Materials and Methods:

Experimental design: 2 factor split plot design at two locations; Saskatoon and Rosthern. 6 replications were used. The main plot was residue treatment and the split-plot was cultivar.

Treatments:

1. Residue management prior to seeding: Spring and fall tillage, spring tillage, stubble burning, and no-till.
   Fall and spring tillage treatments were performed with a heavy duty plot cultivator with tine harrows to a depth of 5-7 cm in 2001 and 2002. A heavy duty plot double disc was used in 2003.
2. Cultivars: Envoy (type 1 navy), and CDC Pintium (type 1 pinto)

The beans were planted in 20.3 cm rows with a target density of 45 plants m^{-2} with granular inoculum in the seed-row. The beans were also treated with Apron FL + Vitaflo 280 at label rates. Production details are listed in Table 16.

Table 16. Seeding Date, average percent emergence, and harvest date for dry bean in 2001-2003

Year	Location	Planting Date	CDC Pintium average % emergence	Envoy average % emergence	Interrow Width (cm)	Harvest date	Soil climatic zone	Soil texture
2001	Saskatoon	May-23	68	65.6	20.3	Sep-26	Dark brown	Clay loam
	Rosthern	May-25	85.1	79.6	20.3	Sep-24	Black	Clay loam
2002	Saskatoon	May-31	72	76.4	20.3	FROST Aug 2	Dark brown	Clay loam
	Rosthern	Jun-03	46.7	60	20.3	FROST Aug 2	Black	Clay loam
2003	Saskatoon	May-29	90.9	84.4	20.3	Sept-04,16	Dark brown	Clay loam
	Rosthern	May-28	85.3	69.8	20.3	HAIL Jul 06	Black	Clay loam

3.4.3 Results and Discussion:

No-till treatments had higher yields than spring tillage, fall + spring tillage and stubble burning treatments (Figure 19). In 2001, no-till treatments yielded significantly higher than all other tillage systems at both Rosthern and Saskatoon ($P<0.05$). Spring tillage yielded higher than fall + spring tillage and stubble burning at both sites, but was significantly lower than no-till. In 2003, no-till was again yielded the highest ($P<0.05$), with no difference between the other treatments. In 2002, both Rosthern and Saskatoon had no yields recorded due to frost on August 2nd and 4th. Biomass samples were taken in soon after the frost, as it was evident that there would be no seed production (Fig.20). No-till and spring till treatments had produced significantly higher amounts of biomass than the removal and fall and spring tillage treatments($P<0.05$). In the two years where the crops were destroyed by frost the biomass of no-till and spring till treatments were higher than the spring + fall tilled treatment and the burned treatment ($P<0.05$) (Figure 20).

We believe that the snow catch from the no-till and spring tilled system resulted in higher soil moisture levels and therefore higher yields. In dry years experienced during this research project, the extra moisture from the snow presumably resulted in higher yields (Fig. 1). In addition, tillage treatments dry out the soil by inverting it and exposing wet soil to be dried.

Beans produced under a no-till system also tended to be taller and have greater pod clearance in some locations (Figures 21 and 22). Plants were significantly taller in no-till and spring till systems than in the fall + spring till and burn treatments at Rosthern and no-till was taller in Saskatoon in 2001. The same trend was seen in 2002 at Rosthern. Saskatoon, however, had no differences observed in plant height in 2002 or 2003. We believe that the differences in height occurred because of better growth from greater moisture in the no-till system and possibly from the reduction in wind speed that the stubble can cause (data not recorded). These differences in height could result in a more effective mechanical harvest.

Given that no-till systems consistently had the highest yield or biomass production in this study we recommend that Saskatchewan dry bean producers utilize a no-till production system. One possible disadvantage of a no-till system is that the soil may not warm up quickly in the spring to facilitate dry bean emergence. In instances where the soil is cold and wet or crop

residue is excessive we would recommend a spring tillage operation. In a previous study we have conducted, it was found in two wet years that the no-till systems had yields similar to no-till. Given this we are confident that dry bean can be successfully produced under no-till conditions in Saskatchewan. Other areas such as Ontario and Manitoba report yield losses when tillage is reduced in bean production. Clearly in Saskatchewan moisture limitations supercede any perceived benefits that could occur with tillage.

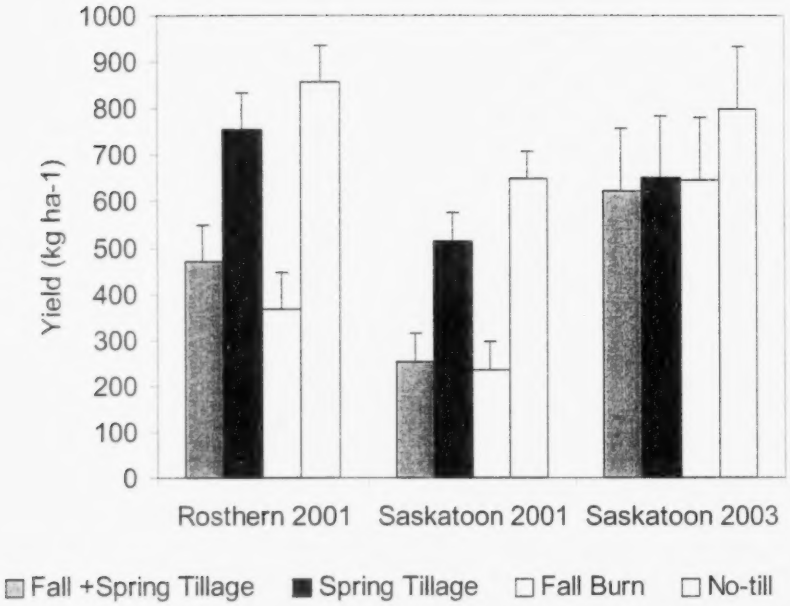


Figure 19. The effect of tillage system on dry bean yield at three site-years.

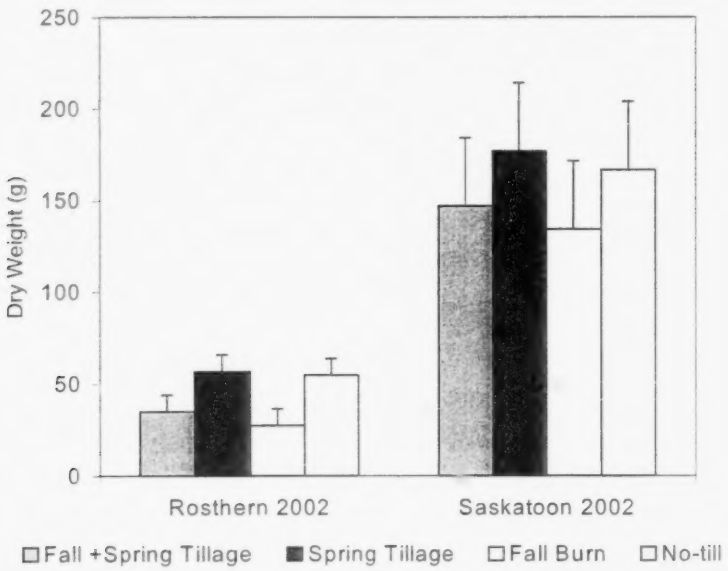


Figure 20. The effect of tillage system on dry bean biomass at two site-years following frost.

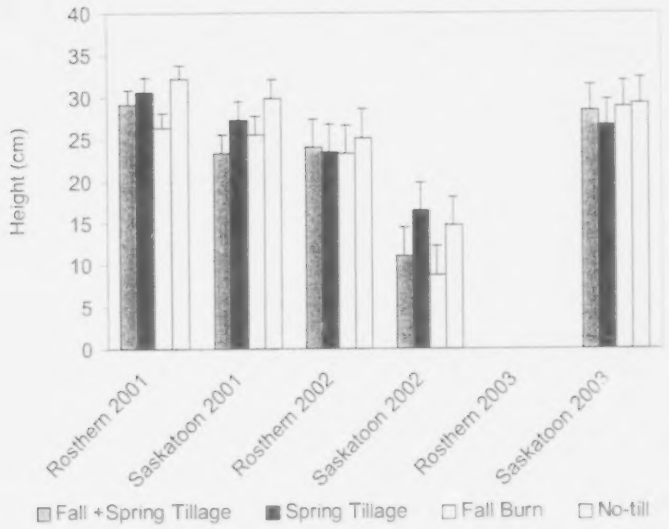
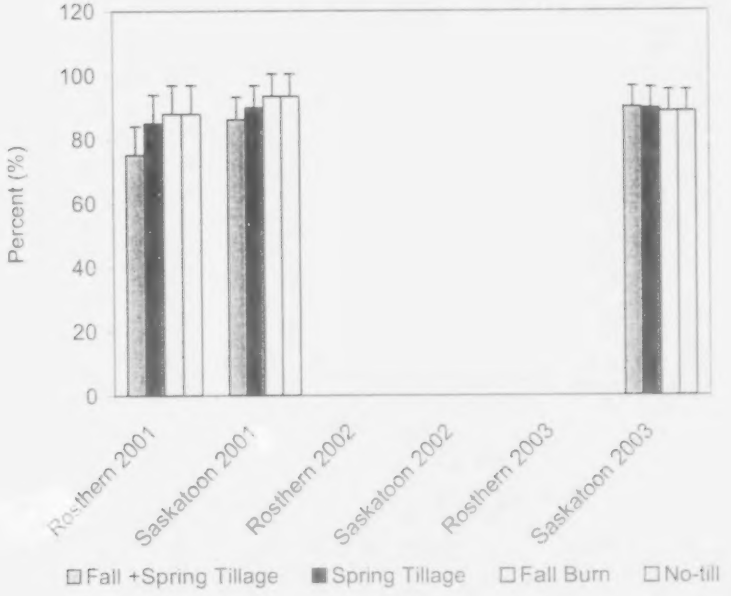


Figure 21. The effect of tillage system on height of dry bean at four site-years.



3.3 Conclusions

1) The dry bean cultivar CDC Pintium does not require inoculation with rhizobium. We have never observed a positive yield response to inoculation.

2) It is usually economic to fertilize CDC Pintium with nitrogen fertilizer under dryland conditions and it is always economical under irrigated conditions. Therefore we recommend that producers apply nitrogen fertilizer. Because of the dry environmental conditions encountered during this research project we cannot make a firm recommendation. However under dryland conditions rates of 50 kg ha^{-1} of actual nitrogen would benefit growth. Under irrigation producers may want to consider higher rates of nitrogen fertilizer (75-100 kg ha^{-1}).

3) Pintium dry beans should be seeded at a rate of at least 40 viable seed m^{-2} under both dryland and irrigated conditions to maximize economic return.

4) The cultivar CDC Pintium is highly adapted to Saskatchewan. Under optimal agronomic inputs it averaged 1200 kg ha^{-1} under dry land production and 3300 kg ha^{-1} under irrigated production (excluding sites where yield was not taken and Melfort 2002). The bean variety Envoy is not adapted for production in Saskatchewan mainly because of its longer maturity and low yield potential.

5) Producers should avoid soaking their beans before seeding if they are not using a seed treatment.

6) Beans produced under a direct seeding no-till system have higher yields in dry years. A spring tillage before seeding does not substantially reduce yield but fall and spring tillage or burning reduces yield potential.

3.4 Information of Benefit to Producers, Processors or Government

All of the above information is of direct benefit to dry bean producers.

5 Equipment

No equipment was purchased.

6 Project Developed Materials

None.

7 Project Photos

None.

8 Acknowledgements

Support for this project was described the Pulse Tour at the Seager Wheeler Farm, 2001, 2002 and 2003; as well as several extension meeting from 2001-2004.